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THE

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Editorial.

Valve Data Diagrams.

IN June, 1931, we described a valve triangle, that is, a diagram, each point of which is at the intersection of three lines drawn from the three corners of an equilateral triangle to meet the opposite sides. The points where these lines meet the opposite sides enable one to read off the three principal characteristics of the valve, *viz.*, the amplification factor, the internal resistance and the mutual conductance. Such a diagram has the advantage of giving one a more comprehensive idea of the properties of a number of valves of various types than could possibly be obtained by means of tabulated data. The particular form of diagram described had, however, several disadvantages; interpolation was difficult because of the radial divergence of the three sets of co-ordinates, and the points tended to become crowded towards certain parts of the triangle. An improvement was introduced by Klingelhöffer and Walther* who described a modified valve triangle in which the crowding of the points was avoided by using logarithmic scales and interpolation was made easier by using parallel co-ordinates; the three sets of co-ordinates cut each other at an angle of 60 degrees, that is to say, they were parallel to the three sides instead of radiating from the corners of the triangle.

A further inprovement has now been devised† which not only allows the three characteristics mentioned above to be read off with great ease and with accurate interpolation, but also gives a fourth characteristic, *viz.*, that which Barkhausen called the "Güte" or quality index of a valve and which is equal to the product of the mutual conductance and the amplification factor.

As will be seen from the figures, the diagram consists of two rectangular co-ordinate systems, one of which is at an angle of 45 degrees to the other. All the four scales are logarithmic. Any valve is represented by a single point; from the vertical and horizontal scales its resistance and quality index and from the sloping scales its mutual conductance and amplification factor can be read off.

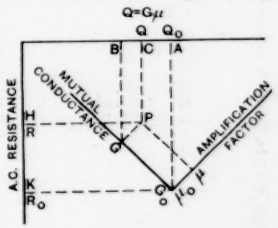

Fig. 1.

In the original diagram the right-hand sloping scale gave the "Durchgriff" which is

* See *Telefunken-Zeitung*, No. 59, 1931, p. 59.

† *Zilitinkewitch.*—Radio (Ukraine), Nov. 1931 and Technika Radio i Slabogo Toka (Russian), Jan., 1932; also *Gundlach.* Elektrische Nachrichten-Technik (German), Sept., 1932.

the reciprocal of the amplication factor, but we have modified it so as to read the more familiar amplification factor μ directly. At the bottom corresponding to a "Durchgriff" D of 0.1 per cent., we have $\mu = 1{,}000$ and at the top $D = 40$ per cent., and $\mu = 2.5$. The scale of mutual conductance G runs from 0.3 to 8.0 mA per volt. All the valves of three German makers were found to lie within these ranges, but there are now screen grid valves with amplification factors greater

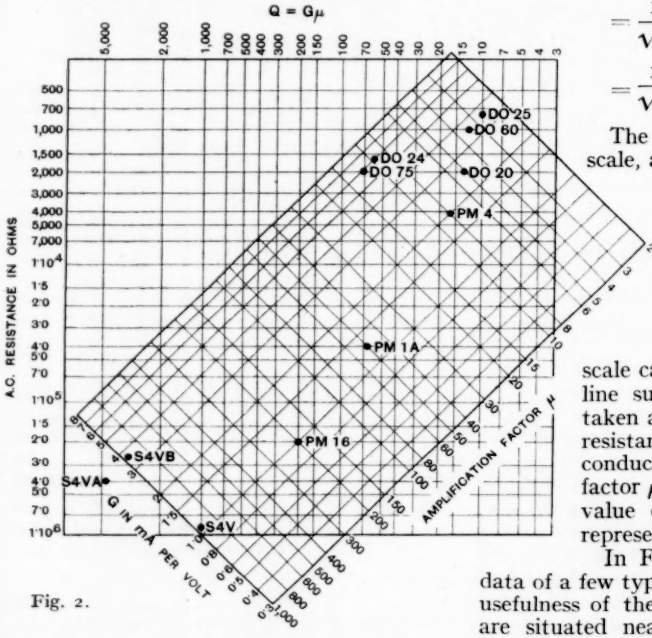

Fig. 2.

than 1,000 and to accommodate them the diagram would have to be extended to the left.

The A.C. resistances cover a very wide range, *viz.*, from about 500 ohms to a megohm, while the quality index varies between 3 and 3,000.

So far as the sloping co-ordinates are concerned, the diagram is an ordinary logarithmic one on which G and μ for each valve are plotted. It is not so obvious that the same points will give the values of R and Q on suitable logarithmic scales on the vertical and horizontal lines, but that this is so can be readily proved.

Let the vertical through the point $G_0\mu_0$ meet the horizontal scale at the point A, and that through any other point P, corresponding to a valve with values G and μ, at the point C. Then

$$AC = AB - BC$$

$$= \frac{1}{\sqrt{2}}[(\log G - \log G_0) - (\log \mu_0 - \log \mu)]$$

$$= \frac{1}{\sqrt{2}}[\log G + \log \mu) - (\log G_0 + \log \mu_0)]$$

$$= \frac{1}{\sqrt{2}}(\log G\mu - \log G_0\mu_0)$$

$$= \frac{1}{\sqrt{2}}(\log Q - \log Q_0)$$

The $1/\sqrt{2}$ is merely a matter of scale, and the formula shows that, if the point A is taken as Q_0, the value of Q corresponding to any point P will be represented by the point C on an appropriate logarithmic scale.

Similarly it can be shown that a logarithmic scale can be plotted on the vertical line such that, if the point K is taken as the value R_0 of the A.C. resistance of a valve with mutual conductance G_0 and amplification factor μ_0, the point H will give the value of R for any other valve represented by the point P.

In Fig. 2 we have plotted the data of a few typical valves to illustrate the usefulness of the diagram. Output valves are situated near the upper corner and screen grid valves near the bottom left hand of the diagram. The S4VA has an amplification factor of 1,500, and is thus somewhat outside the $G - \mu$ co-ordinates, but these could easily be extended further to the left to include such valves. G. W. O. H.

Since writing this note we have discovered that a diagram very similar in principle was described by Dr. R. T. Beatty in the *Wireless World* of July 17th, 1929, and used by him to plot the data of about 100 British valves. In Dr. Beatty's diagram R and G were plotted on the same axes as in Fig. 2 but in the reverse directions, μ was plotted on the horizontal scale, while Q, which is little used in this country, was not given. Dr. Beatty's diagram illustrates the great utility of this type of diagram for plotting the data of a large number of valves in a manner that lends itself to easy classification.

The Existence of More Than One Ionised Layer in the Upper Atmosphere.*

By Geoffrey Builder, B.Sc.
(*King's College, University of London.*)

Introduction.

IN a recent editorial[1] in *The Wireless Engineer*, reference has been made to the problem of the number of ionised layers in the upper atmosphere. It was pointed out that the work of Goubau and Zenneck,[2] on 533 metres, can be interpreted in terms of reflections from a single ionised layer at a height of about 100 kms. Even though this is true it affords no criterion of the number of ionised layers which do actually exist. As will be shown, it is to be expected that these waves would always be reflected at about this height. Since there has now accumulated a large amount of evidence indicating the existence of more than one ionised layer in the upper atmosphere capable of reflecting wireless waves it seems worth while to review the data available from wireless experiments.

Experimental Methods.

There are two important wireless methods of investigating the electrical structure of the upper atmosphere. The "frequency-change" method is due to Appleton and Barnett[3] and has been extensively and successfully used by Appleton and others. A small continuous change is made in the frequency of an unmodulated continuous wave transmitter and the signal amplitude at the receiving station is photographically recorded using an Einthoven galvanometer or other suitable instrument. If two sets of waves are being received simultaneously the equivalent path difference P' between them is determined by the number of interference maxima and minima through which the received signal intensity passes as the change in the transmitter frequency is made. It may be shown[4] that

$$P' = c\delta n/\delta f$$

where

c = the velocity of electromagnetic waves in free space.

δf = the number of cycles per second by which the transmitter frequency is changed.

δn = the number of interference fringes due to the frequency change δf.

and the equivalent path of the wave is given by

$$c\,f\,(1/U)ds$$

where ds is an element of the path and U is the group velocity of the waves at any point.

A typical record obtained by the method is shown in Fig. 1. The mean wavelength was 107 metres and the frequency change 6.30 kc. per sec. The number of interference fringes is 10.7 and therefore the equivalent path difference between the interfering waves was 509 kms. Since the distance between transmitter and receiver was 5 kms., and one of the interfering waves was the direct "ground wave," it is readily calculated that the equivalent height of reflection for the "atmospheric wave" was 257 kms.

The "group-retardation" or "pulse" or "echo" method of Breit and Tuve,[5,6] has been very widely used, with many modifications and improvements. A short pulse of radio-frequency energy is sent out from the transmitter and the nature of the signal

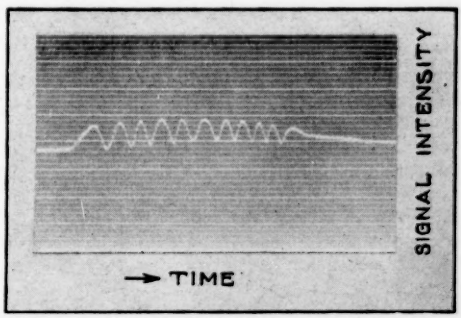

Fig. 1.—*A simple fringe pattern obtained by the frequency change method. Frequency change 6.30 kc/s and equivalent path difference 509 kms.*

at the receiving station is investigated by means of a high-speed recorder such as the cathode-ray or bifilar oscillograph. If there is a multiplicity of paths between the transmitter and the receiver, and if the pulse is

* MS. received by the Editor, March, 1932.

sufficiently short, a signal corresponding to each of the paths is received separately. The time differences between the arrival of the various signals is measured directly from the oscillograms and the equivalent path differences and the equivalent heights may then be calculated. In practice, a uniform sequence of pulses is transmitted with sufficient spacing between them to ensure that the received signals, corresponding to each pulse sent, do not overlap in time. Recent workers have used pulses as short as 1×10^{-4} sec. in duration, sent at a rate of about fifty per second. A typical simple record obtained in this way is reproduced in Fig. 2. The recording instrument was a Duddell oscillograph and a time-base for measurement is given by an oscillation of 1,100 cycles/sec. The pulses marked G are those due to the direct ground signal and are followed by echoes F_1 and F_2 which are first and second reflections from an equivalent height of 254 kms. The distance between transmitter and receiver was 5 kms. and the wavelength 90 metres.

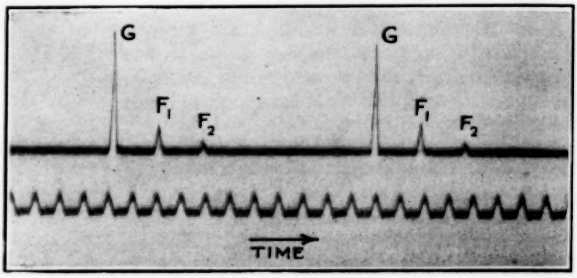

Fig 2.—*First and second reflections from an equivalent height of 254 kms., as recorded by the echo method. Time base oscillator frequency 1,100 c/s.*

Equivalence of the Two Methods.

These two methods, as well as others of less importance, have been compared theoretically by Appleton[7] and Schelleng[8] who showed that the quantities measured by the two methods are generally equivalent. Experiments being carried out by the author indicate the validity of this conclusion. A comparison of their relative advantages for investigating the upper atmosphere has been made by Appleton and Builder[9] who pointed out that the echo pattern is much the simpler to interpret if there is a multiplicity of paths, but that the frequency change method was much more sensitive in the detection of weak signals when a square law detector was used. The use of a linear detector, working at very high levels, for the echo observations, has since shown that the methods are essentially the same in this respect.

The Existence of One Ionised Layer.

The existence in the upper atmosphere of an ionised layer capable of reflecting wireless waves was first directly demonstrated by Appleton and Barnett[3] in 1925, using the frequency change method. Confirmation by the pulse experiments of Breit and Tuve[6] followed shortly afterwards. Appleton and Barnett, using a wavelength of 400 m., measured heights of the reflecting layer varying from 90 kms. in the daytime to 115 kms. at night, while Breit and Tuve found heights ranging from 80 to 200 kms. for 70 m. waves. The latter measurements have, however, not been confirmed, and later Breit, Tuve, and Dahl,[10] with improved pulse transmissions on 75 metres, observed that the heights of reflection measured from successive echoes were sometimes approximately in the ratio 1 : 2 : 4, and interpreted the results in terms of multiple reflections at a single layer although the relative intensities and the relative delays of the echoes are scarcely compatible with the explanation. Kenrick and Jen[11] obtained equivalent heights of the reflecting layer for 67 metre waves of 250 kms. in the daytime to 350 kms. at night. These values, together with those of Hollingworth[12] on 14,350 metres, Appleton and Barnett[13] on 400 metres and Heising[14] on 57 and 111 metres were employed to obtain a curve relating equivalent height and wavelength, and it was shown that the result was not incompatible, qualitatively, with the curve calculated on the assumption of a single reflecting layer.

Quantitatively, agreement was not good and the greater range of measurements now available indicate that the agreement of the shape of the experimental and calculated curves was fortuitous. Further, the single layer theory does not account for the observed relation of attenuation to wavelength, as has

been pointed out by Heising,[14] Eckersley,[15] and others. To explain the marked superiority of the shorter waves for long-distance communication it is necessary to assume a distinct attenuating region below the reflecting layer at which reflection of the short waves occurs.

TWO IONISED LAYERS.

Frequency Change Measurements.

In 1927 Appleton[16] demonstrated the existence of two distinct regions of ionisation at heights of about 100 and 200 kms. Using the frequency-change method many of the records showed subsidiary fringes superimposed on the main ones. At a wavelength of 1,000 metres, it was always found that these subsidiaries could be accounted for in terms of multiple reflections between the ground and a single ionised layer (the Kennelly-Heaviside or *E* layer) at a height of about 100 kms. With 400 metre waves similar results were usually obtained, but in some records taken in the early morning the subsidiary fringes could not be explained in this way. A careful examination showed that the ratio of the number of primary to subsidiary fringes was not that to be expected on the assumption of multiple reflections from a single layer. Moreover, in the period just before sunrise, the primary fringes disappeared on some occasions, the subsidiary then becoming the main fringes. In these cases the primary fringes suddenly returned at about 40 minutes before sunrise at the ground, while the subsidiaries gradually weakened and disappeared.

The difficulty of interpreting such records in terms of a single reflecting layer led Appleton to postulate a second ionised layer (*F* layer) at a height of about 200 kms. and considerably richer in ionisation than the lower layer. On this basis, the subsidiary fringes are due to the radiation partly or completely penetrating the lower layer and being reflected at the upper one. The sudden return to reflection at the *E* layer, at about 40 minutes before ground sunrise, agrees well with the time of sunrise at the height of this layer. Another feature of the records which is similarly explained is that the equivalent height of *F* layer, deduced from the subsidiary fringes, began to decrease at about 80 minutes before sunrise.

Further evidence pointing to the correctness of this hypothesis was obtained by Appleton and Ratcliffe[17] in simultaneous observations at a number of stations receiving signals from the same transmitter. Simultaneous reflections from different layers at different receiving stations were observed at wavelengths of 400 and 212 metres, and it was found that the *E* and *F* layer heights did not differ greatly for these two wavelengths. Appleton and Green[18] found that only during part of the daytime is the ionisation of *E* layer great enough to reflect 100 metre waves. Fig. 3, from their paper, shows the variation of equivalent height of the reflecting layer throughout the day measured on this wavelength. The discontinuities in the curve indicate definitely the distinct nature of the two layers, especially when it is remembered that for the greater part of the night and throughout the day 400 metre waves are reflected at a height of about 100 kms.

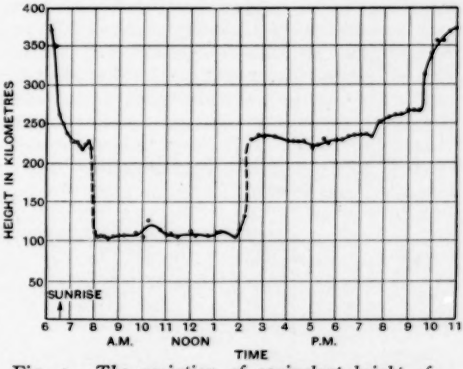

Fig. 3.—*The variation of equivalent height of reflection of* 100 *m. waves on October* 21, 1928. (*After Appleton & Green.*)

The frequency-change measurements therefore indicate that (*a*) 1,000 metre waves are always reflected at *E* layer at an equivalent height of about 90 kms., (*b*) 400 metre waves are reflected at E layer at an equivalent height of 90 kms. in the daytime to 115 kms. at night, except for short periods before sunrise when recombination in *E* layer has proceeded so far as to permit its penetration by these waves so that reflection may occur at *F* layer at about 200 kms., (*c*) the behaviour of 200 metre waves is very similar except for such differences as might have been expected: slightly greater equivalent heights for both layers and a greater ten-

dency to penetrate the lower layer, and (*d*) at 100 metres penetration of the lower layer occurs for the greater part of the day. Equivalent heights on this wavelength are about 105 and 230 kms. in the daytime to more than 360 kms. at night.

Group-retardation Measurements.

Appleton[19] has interpreted the results of Breit, Tuve, and Dahl, already referred to, as confirming the hypothesis of two reflecting layers. The three echoes received indicated equivalent heights of 105, 235 and 470 kms., the departure from the ratio 1 : 2 : 4 being outside the limits of experimental error. If the three echoes are multiple reflections from a single layer it is to be noted that the third reflection is consistently absent, and that in the published records the first echo is frequently weaker than the second. These difficulties disappear at once if the echoes are interpreted as a single reflection from *E* layer and first and second reflections from *F* layer. The heights of the two layers so obtained are in good agreement with the daytime frequency-change measurements made on 100 metres.

In 1930 Gilliland,[20] using 74 metres, concluded that the down-coming signals during the day were due to two layers at equivalent heights of 119 and 235 kms. Appleton and Builder[21] have published successive echo records showing the penetration of the lower layer by 80 metre waves in the sunset period. Similar records for 90 metres, in Fig. 4, taken at 9, 10 and 11 o'clock G.M.T., show the gradual change over of reflection at *F* layer to reflection at *E* layer as the ionisation of *E* layer increases. The non-occurrence of multiple echoes in these records is due partly to the use of a square law detector and partly to attenuation, probably occurring in *E* layer.

Schafer and Goodall[22], using 185 and 97 metres simultaneously, provided further striking evidence in favour of the two-layer theory. Curves of equivalent height against time showed, for the longer waves, a sudden change over of reflection from the upper to the lower layer, while the shorter waves continued to be reflected by the upper layer. Further, it was shown that waves just short enough to penetrate the lower layer suffered considerable group retardation so that the equivalent height of *F* layer measured on this wavelength was appreciably increased. This effect has previously been discussed by Appleton and Ratcliffe[23] and by Appleton,[24] and is further illustrated in Fig. 5, in which the variation of the equivalent height of the reflecting layer for 80 metre waves and the intensity of the *F* layer reflections are plotted against time. Until 1620 G.M.T. reflection from *E* layer occurred, but the waves then penetrated this layer and were reflected at *F*. The *F* echoes were at first weaker and indicated greater equivalent heights than later when the *E* layer ionisation had further decreased. The reverse process then occurs when *E* layer ionisation again increases sufficiently to reflect. The inverse correlation of *F* layer height and echo intensity is very marked in this as in many other similar records.

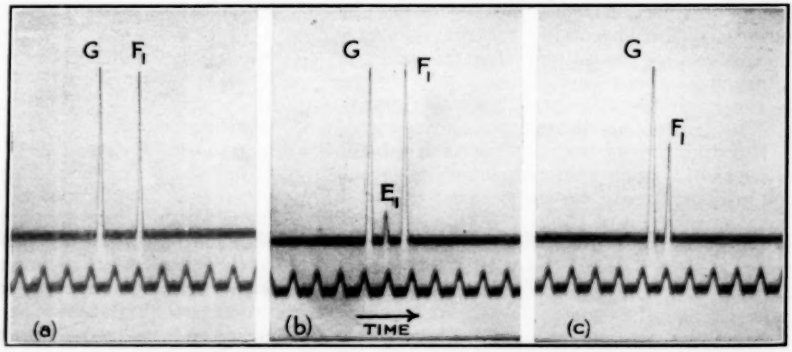

Fig. 4.—*Successive echo records showing a change over of reflection from F layer to E layer and illustrating the distinct nature of the two layers.*

More recently further observations by Gilliland, Kenrick and Norton,[25] Ranzi,[26] and others have added an abundance of evidence in favour of the hypothesis of a second re-

flecting layer. It is to be noted that there is no definite evidence of reflections from heights intermediate between those given for the E and F layers except those of Goubau and Zenneck[2] to which we now

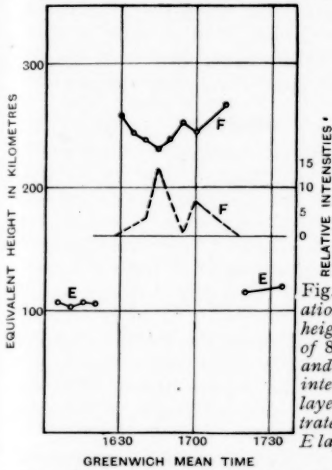

Fig. 5.—*The variation of equivalent height of reflection of 80 metre waves and the variation of intensity of the F layer echoes, illustrates the effect of E layer on F layer echoes.*

turn. From what has been said, the failure to observe echoes from F region is not surprising in view of the wavelength used in the experiments and the results are in this respect compatible with the simple two-layer theory. It is to be noted, however, that while the frequency change measurements gave values of 90 to 115 kms. for 400 metres, Goubau and Zenneck measured equivalent heights up to 140 kms. for 533 metres. The echoes from which these higher values were calculated were usually accompanied by others giving the more usual heights of 90 to 100 kms. The authors show that for the most part the equivalent heights may be divided into two groups at about 95 and 135 kms. Such a grouping does not suggest either a continuous layer of ionisation extending upwards from 90 kms. or that the double and complex echoes are due to undulations in the layer as suggested by the authors. It is therefore necessary to consider whether these complex echoes, which generally occurred in the early morning hours, indicate a stratification of E layer or whether there is any other probable explanation.

Are there more than Two Ionised Layers or are these Layers Horizontally Stratified?

Eckersley[15] considers that the available data suggests horizontal stratification of the F layer, the maxima of ionisation being about 10^5 electrons per cc. at 100 kms. (E layer) and 3×10^5 and 9×10^5 at 180 and 250–350 kms. respectively (F layer). The variation of equivalent height with wavelength does not appear to require such stratification, and the variation of equivalent height of the F layer for a given wavelength is scarcely compatible with such a hypothesis since the equivalent height increases smoothly as recombination proceeds until such time as the ionisation is no longer sufficient to cause reflection of the waves being used. There is no sudden jump to a higher stratum such as occurs in the case of penetration of E layer and more evidence is necessary before further complication of the layer structure need be postulated. The results of Goubau and Zenneck may at first appear to support a similar hypothesis for the E layer unless their own explanation of complex echoes due to scattering at an undulatory layer is accepted. Appleton and Builder[9] have obtained double echoes from the F layer on 80 metres under somewhat similar conditions but consider that they may be the two magneto-ionic components due to splitting of the original signal into two polarised components having different group velocities in an ionised medium in the earth's magnetic field.* The occurrence of such splitting at times when the waves may be supposed to penetrate far into the ionised layer, the gradual increase from zero of the time interval between the components as such penetration occurs, and the different electron densities required for the reflection of the components, are all in accord with the explanation. Fig. 6 shows an echo record which is typical of such splitting of the F echo. Under other conditions echo patterns like that of Fig. 7 are frequently obtained owing to multiple splitting. Transitions between these two types are also observed, the two main components both showing signs of complexity but remaining distinct. If the explanation advanced is correct it accounts for such complex echoes without the need to assume further complexity in the layers themselves.

There is another type of echo pattern which at first sight might seem to suggest

* Since this paper was written this hypothesis has been confirmed. A full account will be available shortly.

the existence of more than two layers but may be very simply explained on the two-layer theory. When the wavelength being employed is such that partial penetration of the E layer occurs and echoes are received simultaneously from the E and F layers, it is to be expected, by analogy with multiple reflections from a single layer, that echoes will also occur due to successive reflections from the two layers. Echoes are in fact observed corresponding to an equivalent height equal to the sum of the equivalent heights of the E and F layers, as measured from the corresponding echoes on the same record. There is also some evidence that reflection from the top of the E layer may occur. Echoes are occasionally observed corresponding to an equivalent height approximately equal to twice the equivalent height of the F layer less the equivalent height of the E layer and may possibly be due to such reflections since they seem to occur only when the critical penetration wavelength for the lower layer is being used.*

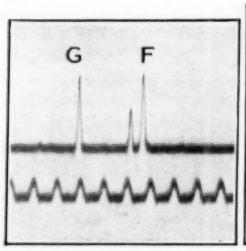

Fig. 6.—*Splitting of the F-layer echo into two components of different retardation.*

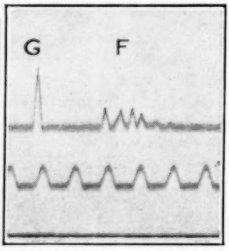

Fig. 7.—*A complex F-layer echo which may be due to magneto-ionic dispersion.*

At present it does not appear essential to postulate more than two layers or stratification of these two layers to explain the experimental data, nor does it appear to be necessary, for observations such as those described here, to assume an undulatory nature for the two layers, but further detailed evidence is required on these points. The occurrence of further strata is not incompatible with the generally assumed mechanism of the ionisation of the layers. Moreover, by the methods described, a layer of ionisation would not be detected if it was above another layer more intensely ionised.

* The fuller investigation of the magneto-ionic effect indicates that simultaneous reflection from the two layers is partly due to the greater electron density required to reflect the left-handed polarised component, which may penetrate the lower layer and be reflected at the upper, while the right-handed component is reflected by the lower layer. Successive reflections at the two layers are therefore not observed as frequently as might be expected from the frequent occurrence of simultaneous echoes from the two layers.

Summary.

The chief wireless methods of investigating the electrical structure of the upper atmosphere are briefly described and compared. It is shown that the results obtained by both methods support the hypothesis of the existence of at least two layers of ionisation capable of reflecting wireless waves. The possibility of the occurrence of other strata of ionisation is also briefly discussed and it is concluded that the measurements available do not require the existence of more than two simple layers of ionisation for their explanation.

I am indebted to Professor Appleton and Mr. A. L. Green, and to the Royal Society for permission to reproduce the diagram of Fig. 3.

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Further Note upon the Pentode with Capacitive Coupling.*

By L. G. A. Sims, Ph.D., A.M.I.E.E.

IN a recent paper† the Author showed that the load-matching conditions which apply particularly in an output stage employing a pentode enable the output coupling capacity to improve materially the low-frequency power response of the stage. The preliminary analysis of the case given in the paper was intended mainly to establish the existence of this effect and a further contribution containing detailed extensions was promised.

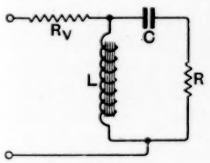


Fig. 1.

Let Fig. 1 represent the equivalent circuit of a valve coupled to a resistance load by means of an inductance L and condenser C, the symbols R_v and R relating to the operating resistance of the valve and to the load respectively.

It was shown that, per volt available in the anode circuit, the volts V developed across the load R were given by

$$V = \frac{\omega LR}{\left[\left(RR_v + \frac{L}{C}\right)^2 + \left\{\omega L(R + R_v) - \frac{R_v}{\omega C}\right\}^2\right]^{\frac{1}{2}}} \quad .. \quad .. \quad .. \quad (1)$$

where $\omega = 2\pi \times$ frequency.

Treating ω as the independent variable in order to examine the behaviour of V with change of frequency, and treating all other quantities as constants, the equation

$$\frac{dV}{d\omega} = 0 \quad .. \quad .. \quad (2)$$

leads to a condition of maximum voltage and therefore of maximum power in R when ω has the special value‡

$$\omega = \left[\frac{1}{C\left(L - \frac{R^2C}{2}\right) - \frac{L^2}{2R_v^2}}\right]^{\frac{1}{2}} \quad .. \quad (3)$$

In the Author's previous paper this equation was examined in order to see whether real values of ω could be expected in practice, that is, whether a peak in the power response curve could be expected. It was found that, with the load-matching conditions usually employed, such a peak could only be expected with pentode valves because the peak occurs only when, among other conditions, the load resistance is less than that of the valve—a characteristic of the pentode but not of the triode output stage.

If typical values of L, R and R_v be inserted in equation (3) and ω be evaluated for different values of C, it is found that ω approaches

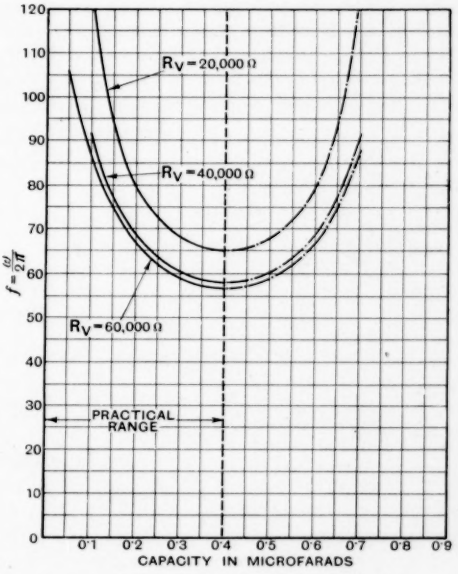


Fig. 2.—*Curves plotted from equation* (3). L = 40 *henrys*, R = 10,000 *ohms*.

infinity for two different values of C. In Fig. 2 are plotted three curves which illustrate this effect, relating to different constant values of R_v.

In order to interpret these curves it is

* MS. received by the Editor, June, 1932.

† *See* "Capacitive Output Coupling," Sims, *Wireless Engineer and Experimental Wireless*, June, 1932.

‡ *Ibid.*, page 315.

necessary to examine them with reference to Table I (which gives figures from which the curve of Fig. 2 relating to $R_v = 60{,}000$ ohms was calculated) and with reference to experimental results taken with circuit constants approximating closely to those assumed in calculation. Fig. 3 shows a series of such experimental results taken with an Osram type PT 240 pentode whose rated internal resistance is 55,000 ohms. The output inductance, measured in the circuit with the load disconnected but with the steady valve current flowing, was 40 henrys, and the load was a non-inductive resistance of 10,000 ohms. These values correspond closely to those assumed in the calculation of Table I, namely $L = 40$ henrys, $R_v = 60{,}000$ ohms, $R = 10{,}000$ ohms. The experimental curves were taken with a constant input of 1.6 volts R.M.S. to the grid of the pentode at a large number of frequencies between 45 and 6,000 cycles per second, the circuit diagram being as shown in Fig. 4. It is seen that the frequency and hence the pulsatance ω at which the power peak occurs, falls continuously as the coupling condenser is increased from 0.05 microfarad to a value between 0.3 and 0.4 microfarad, the peak vanishing for values of

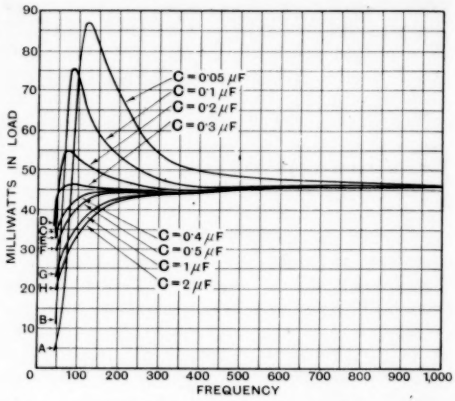


Fig. 3.—*Experimental power response curves of Pentode PT240. Choke-condenser coupled to resistance load of* 10,000 *ohms.* $R_v \doteqdot 55{,}000$ *ohms,* $L \doteqdot 40$ *henrys, under operating conditions. Input to grid* = 1.6 *v. R.M.S.*

TABLE I.

CALCULATION OF ω FROM EQUATION (3).

$L = 40$ hys. $R_v = 60{,}000\ \Omega$. $R = 10{,}000\ \Omega$. C variable.

C in μF.	$\frac{R^2C^2}{2}$	$\frac{L^2}{2R_v^2}$	$\frac{R^2C^2}{2} + \frac{L^2}{2R_v^2}$	LC	$LC - \frac{R^2C^2}{2} - \frac{L^2}{2R_v^2}$	$\frac{1}{LC - \frac{R^2C^2}{2} - \frac{L^2}{2R_v^2}}$	$\omega = \frac{1}{\sqrt{LC - \frac{R^2C^2}{2} - \frac{L^2}{2R_v^2}}}$	$f = \frac{\omega}{2\pi}$
0.05	$\frac{0.125}{10^6}$	$\frac{0.222}{10^6}$	0.347×10^{-6}	2×10^{-6}	1.653×10^{-6}	6.04×10^5	729	116
0.1	$\frac{0.5}{10^6}$	,,	0.722×10^{-6}	4×10^{-6}	3.278×10^{-6}	3.05×10^5	553	88.2
0.2	$\frac{2.0}{10^6}$	,,	2.222×10^{-6}	8×10^{-6}	5.778×10^{-6}	1.73×10^5	417	66.4
0.3	$\frac{4.5}{10^6}$	,,	4.722×10^{-6}	12×10^{-6}	7.278×10^{-6}	1.375×10^5	371	59
0.4	$\frac{8}{10^6}$	,,	8.222×10^{-6}	16×10^{-6}	7.778×10^{-6}	1.285×10^5	358	57
0.5	$\frac{12.5}{10^6}$	,,	12.722×10^{-6}	20×10^{-6}	7.278×10^{-6}	1.375×10^5	371	59
0.6	$\frac{18}{10^6}$	,,	18.222×10^{-6}	24×10^{-6}	5.778×10^{-6}	1.73×10^5	417	66.4
0.7	$\frac{24.5}{10^6}$	,,	24.722×10^{-6}	28×10^{-6}	3.278×10^{-6}	3.05×10^5	553	88.2
0.8	$\frac{32.0}{10^6}$	,,	32.222×10^{-6}	32×10^{-6}	Negative	Negative	Imaginary	Imag.
0.9	$\frac{40.5}{10^6}$	,,	40.722×10^{-6}	36×10^{-6}	Negative	Negative	Imaginary	Imag.

capacity greater than this. If reference be made to Fig. 2 it will be seen that the experimental results agree fairly closely with the theoretical prediction given by the first half of the curve relating to $R_v = 60{,}000$ ohms. This curve shows that no peak is to be expected for lower frequencies than about 57 cycles per second, and that a capacity of about 0.4 microfarad is then needed.

For larger values than 0.4 microfarad the theoretical and experimental curves no longer agree, as the former appear to indicate a further range of frequencies over which a power peak will occur with further increase of capacity, whilst the latter show that, in fact, the power response curve degenerates with increasing C to the form characteristic of plain transformer coupling, that is, the low-frequency response falls away.

Case of "Level Compensation."

It follows, therefore, that only the first halves of the curves shown in Fig. 2 have practical value. At the same time, it is made clear that an important practical case arises at what may be called the critical or transition point of these curves, namely, the point of minimum frequency. Here the capacity becomes such as to maintain uniform response over the widest possible range of frequencies (see Fig. 3). This, then, gives the condition for what may be termed "level compensation."

Referring to the figures in Table I, it is seen that this condition arises when the denominator of the expression for ω, defining ω for maximum power, has its greatest value. From this we may determine an expression for the capacity which yields level compensation in a given pentode output circuit. Writing for the denominator expression of (3)

$$m = LC - \frac{R^2C^2}{2} - \frac{L^2}{2R_v^2} \quad .. \quad (4)$$

we may differentiate m with respect to C and equate to zero to determine conditions for a maximum.

Thus $$\frac{dm}{dC} = L - \frac{2CR^2}{2} \quad .. \quad (5)$$

Equating to zero gives

$$L = CR^2$$

Whence, if C' be written to denote a special value of C applying to this case

$$C' = \frac{L}{R^2} \quad .. \quad .. \quad (6)$$

Inserting the values $L = 40$ henrys, $R = 10{,}000$ ohms into (6) and converting to microfarads gives $C' = 0.4$ microfarad, which agrees satisfactorily with Figs. 2 and 3 and Table I and confirms that (6) gives a maximum value of m and a minimum value of ω.

The value of capacity for level compensation is shown by (6) to be independent of R_v, a result which is also demonstrated by the curves of Fig. 2.

But although this is so, the lowest frequency of uniform response is a function of R_v (see Fig. 2). Clearly, by substituting from (6) in (3) this frequency can be determined. The substitution yields

$$\omega' = \frac{1}{\left[\frac{L^2}{R^2} - \frac{L}{2} - \frac{L^2}{2R_v^2}\right]^{\frac{1}{2}}}$$

where ω' represents the special value of ω associated with C'.
Then

$$\omega' = \frac{\sqrt{2} \cdot RR_v}{L(R_v^2 - R^2)^{\frac{1}{2}}} \quad .. \quad (7)$$

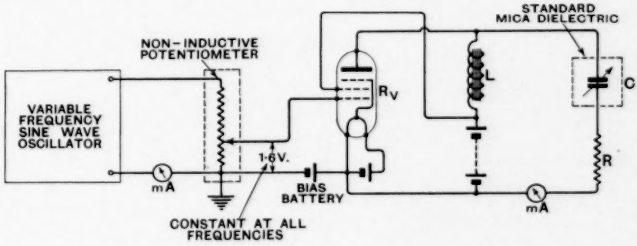


Fig. 4.

whence by writing $f' = \frac{\omega'}{2\pi}$ we have

$$f' = \frac{0.225\ RR_v}{L \cdot (R_v^2 - R^2)^{\frac{1}{2}}} \quad .. \quad (8)$$

Substituting in (8) the values $R_v = 60{,}000$ ohms, $R = 10{,}000$ ohms, $L = 40$ henrys, as used in Table I, gives $f' = 57$ cycles per second for the lowest frequency of uniform response. This agrees exactly with the

figures calculated from equation (3) in Table I and is confirmed to a reasonable degree of approximation by the experimental curves. Thus equations (6) and (8) may be used to determine the coupling capacity and lowest frequency of uniform response.

Throughout the above reasoning a load resistance of 10,000 ohms has been employed and a transformation ratio of unity assumed at the inductance. Inevitably the varying frequency under which the output stage works in practice must complicate the theory when the true nature of the load is a complex impedance, as is the case with a loud speaker; nor could full allowance be made for this. But at the very low frequencies concerned throughout the analysis the load certainly tends to become predominantly ohmic in character,* which makes its treatment as a resistance a reasonable approximation. Since the ratio of transformation, if not unity, appears in the equations merely as a constant multiplying the actual values of resistance and capacity in the secondary circuit, it does not affect the general conclusions reached. If, for example, the ratio of primary turns to secondary turns be k, and the actual load resistance and coupling capacity be R_2 and C_2, the substitutions

$$R = k^2R_2, \quad C = \frac{C_2}{k^2}$$

throughout the solutions will allow for all ratios of transformation.

With pentode valves, except when used with low-resistance moving-coil speakers, the value of k is usually close to unity, and the properties of the auto-transformer of low ratio then reduce the effective series impedances of the transformer windings to values which are negligible at low frequencies, so justifying their omission from the analysis. On the other hand, the magnetising current at the lowest frequencies is by no means negligible and is taken into account in equation (1).

Capacity for Maximum Power at a Particular Frequency.

If equation (1) be differentiated with respect to C (ω being taken as constant) a solution may be derived which gives the value of C required for over-compensation of the bass response at a chosen frequency, so enabling the low-frequency response of an imperfect reproducer to be augmented. Thus, whereas the analysis has so far aimed at adjusting the characteristics of the output stage to equal, as far as possible, those of a supposed perfect reproducer, the present analysis will aim at improving the response of the complete stage, including the reproducer.

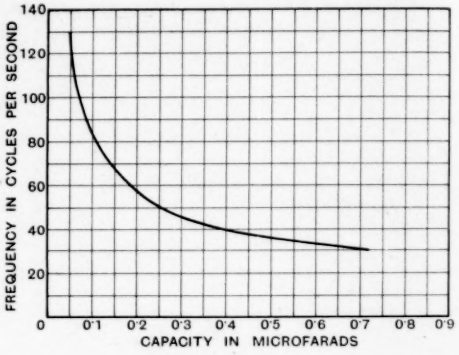


Fig. 5.

Expanding the denominator of (1) and writing

$$\beta = RR_v$$
$$\delta = \omega LR$$
$$\epsilon = \omega L(R_v + R)$$

we have

$$V = \frac{\delta}{\left[\beta^2 + 2\frac{\beta L}{C} + \frac{L^2}{C^2} + \epsilon^2 - 2\frac{\epsilon R_v}{\omega C} + \frac{R_v^2}{\omega^2 C^2}\right]^{\frac{1}{2}}} \quad .. \quad .. \quad (9)$$

Differentiating and writing (D) for the denominator expression when this recurs unchanged from (9) we have, after simplification

$$\frac{dv}{dc} = -\frac{\delta\left[\frac{1}{C^2}\left(\frac{\epsilon R_v}{\omega} - \beta L\right) - \frac{1}{C^3}(R_v^2 + L^2)\right]}{[D]^2} \quad .. \quad .. \quad (10)$$

The condition for maximum voltage across the load, and hence for maximum power, is obtained from (10) in the usual way by

* See "The Inductor Dynamic Loud Speaker." Oliver, *The Wireless World and Radio Review*, 18th November, 1931.

equating to zero. This leads to the equation

$$\left[\frac{1}{C^2}\left(\frac{\epsilon R_v}{\omega} - \beta L\right) - \frac{1}{C^3}(R_v^2 + L^2)\right] = 0$$

whence, after multiplying by C^2 and collecting terms we have

$$C'' = \left[\frac{\frac{R_v^2}{\omega^2} + L^2}{\frac{\epsilon R_v}{\omega} - \beta L}\right]$$

where C'' is written to denote a special value of C.

Substitution for ϵ and simplification yield

$$C'' = \left[\frac{R_v^2 + \omega^2 L^2}{\omega^2 L R_v^2}\right] \quad .. \quad (11)$$

This equation, therefore, defines the capacity in farads which will develop the maximum possible power in the load at any selected single value of ω. It is of interest to note that this capacity is a function of the valve resistance R_v but not directly of the load resistance R, though the latter may operate upon C indirectly by virtue of its influence in a rational selection of the inductance L*. But, unlike the analysis relating to variable ω (equation 3), the result expressed for variable C in equation (11) does not permit imaginary values due to the rélative magnitudes of R_v and R. There is consequently an optimum capacity for both pentode and triode which, theoretically, will yield maximum power at any one frequency since the pentode and triode output circuits, for the purpose of this analysis, are to be regarded as differing only in the relations between R_v and R. But it will be shown that, in practice, the solution is virtually applicable only to the pentode.

In Fig. 5 values of capacity and frequency are plotted from (11) for a pentode circuit having the constants previously employed, namely, $R_v = 60{,}000$ ohms, $L = 40$ henrys, $R = 10{,}000$ ohms. From this curve can be read the capacity required for maximum power at any one frequency. In Fig. 6 are shown experimental curves taken with an Osram pentode, type PT 240, nominal internal resistance 55,000 ohms, the other circuit constants being $L = 40$ henrys (approximately) and $R = 10{,}000$ ohms. The circuit was the same as shown in Fig. 4, but the frequency was maintained constant during each test and the capacity varied. Comparison of the theoretical curve of Fig. 5 with the measured values from Fig. 6 shows satisfactory agreement and confirms that equation (11) defines conditions for maximum power.

* *Ibid.*, pages 316 and 317.

The "Coincidence" Effect.

If curves for the two foregoing cases, relating to the same circuit constants, be superimposed it would appear possible that an intersection may occur and fall within what is termed in Fig. 2 the "practical range." At the intersection the conditions for maximum power defined by equations (3) and (11) will be satisfied simultaneously and the power developed in the load will attain its maximum possible value.

In Fig. 7 curves plotted from equations (3) and (11) for $R_v = 60{,}000$ ohms, $R = 10{,}000$ ohms and $L = 40$ henrys are shown superimposed, intersection occurring at a frequency of approximately 108 cycles per second and with a capacity of approximately

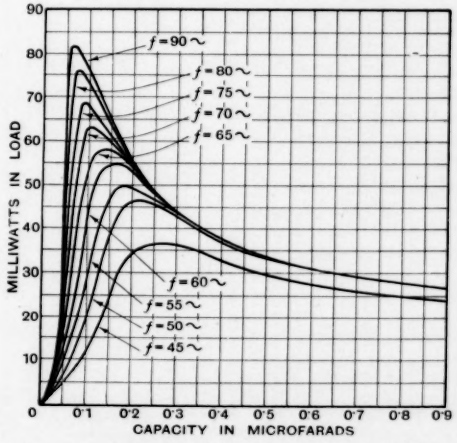


Fig. 6.—*Experimental curves of coupling capacity and power plotted from response curves for different frequencies. Pentode PT240, resistance load = 10,000 ohms. Choke inductance under operating conditions = 40 henrys.*

0.07 microfarad. As the above circuit constants correspond with those used in the experimental tests, it follows that, in the measured response curves of Fig. 3, the power peak shown in the curve for $C = 0.05$ microfarad is approximately the greatest

obtainable with that circuit, and that, if further tests with smaller capacities had been carried out, the peak, whilst occurring at higher frequencies, would diminish in amplitude.

Throwing equation (11) into a form for the determination of ω in terms of C, L, and R_v we have

$$\omega^2 C L R_v^2 = R_v^2 + \omega^2 L^2$$

whence

$$\omega = \frac{R_v}{(C L R_v^2 - L^2)^{\frac{1}{2}}} \quad .. \quad (12)$$

For coincidence between the values of ω defined by (3) and (12) we may write

$$\frac{R_v}{(C L R_v^2 - L^2)^{\frac{1}{2}}} = \frac{1}{\left(CL - \frac{R^2C^2}{2} - \frac{L^2}{2R_v^2}\right)^{\frac{1}{2}}}$$

whence

$$R_v^2\left(CL - \frac{R^2C^2}{2} - \frac{L^2}{2R_v^2}\right) = CLR_v^2 - L^2$$

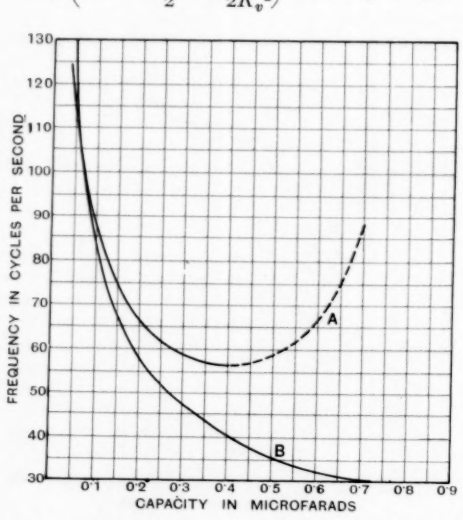


Fig. 7.—*Curve A plotted from equation* (3). *Curve B plotted from equation* (11).

Solving for C we have

$$C^2 R_v^2 R^2 = L^2$$

whence

$$C''' = \frac{L}{RR_v} \quad .. \quad .. \quad (13)$$

where C''' is in farads and represents the special value of C for this case.

Equation (13) therefore defines the capacity which will produce the utmost possible power peak.

The pulsatance ω''' at which the coincidence peak will occur can be found by substituting for C''' in either (3) or (11). Taking the latter case we have

$$\omega''' = \left[\frac{1}{\frac{L^2}{RR_v} - \frac{R^2L^2}{2R^2R_v^2} - \frac{L^2}{2R_v^2}}\right]^{\frac{1}{2}}$$

whence

$$\omega''' = \frac{1}{L}\left[\frac{RR_v^2}{R_v - R}\right]^{\frac{1}{2}} \quad .. \quad (14)$$

Inspection of (14) shows that ω''' is real only when R_v is greater than R. Therefore, when the usual load-matching relationships between R_v and R for pentode and triode are employed, the "coincidence effect" is confined to the pentode circuit.

Substitution of the values $R_v = 60{,}000$ ohms, $R = 10{,}000$ ohms, $L = 40$ henrys in (13) and (14) gives values of capacity and frequency of 0.067 microfarad and 108 cycles per second: these agree with the intersection shown by the curves of Fig. 7.

Summary.

The foregoing results may be summarised as below, the meanings of the various symbols being given by the circuit diagram of Fig. 1.

Case 1.—*Compensation of Power Response Curve for Uniform Response to Lowest Possible Frequency.* (*Level Compensation*).

$$C' = \frac{(10^6 L)}{R^2}$$

where C' is expressed in microfarads.

$$f' = \frac{0.225 R R_v}{L(R_v^2 - R^2)^{\frac{1}{2}}}$$

where f' is the lowest frequency at which uniform response can be maintained.

Case 2.—*Over-compensation of Power Response Curve at a Particular Low Frequency.*

$$C'' = 10^6 \cdot \left[\frac{R_v^2 + \omega^2 L^2}{\omega^2 L R_v^2}\right]$$

where C' is expressed in microfarads and $\omega = 2\pi \times$ (frequency at which over-compensation is desired).

Case 3.—Maximum Possible Low Frequency Power—the Coincidence Case.

$$C''' = \frac{10^6 \cdot L}{RR_v}$$

$$f''' = \frac{1}{2\pi L}\left[\frac{RR_v^2}{R_v - R}\right]^{\frac{1}{2}}$$

where C''' is in microfarads and f''' is the frequency at which augmentation will occur.

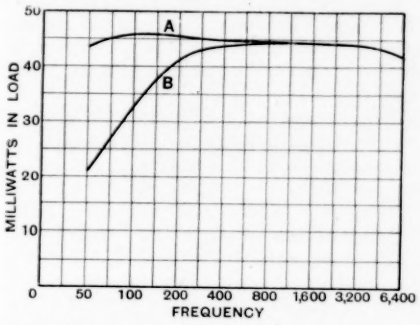


Fig. 8.—Experimental power response curves for Pentode PT240 choke-condenser coupled to resistance load. Curve A, coupling capacity, = 0.3 μF. Curve B, standard coupling condition C = 2.0 μF. Choke inductance = 40 henrys. Transformation ratio = 1.

It was pointed out in the analysis of Case 2 that the result applies to both triode and pentode. In practice, however, the over-compensation effect is sharply defined and of appreciable magnitude with the pentode, but ill-defined and of little acoustic significance with the triode. This results, as will be understood from a general explanation given in the Author's previous paper, from the much higher internal resistance of the pentode and its comparatively low resistance load. Moreover, as the effect is due to resonance between the coupling inductance and condenser, and the desired frequency of over-compensation is likely to be of the order 50 cycles per second, it follows that the triode, with its low inductance coupling, calls for a very large condenser. Thus, for a triode of 1,500 ohms internal resistance coupled to a load of 3,000 ohms, a coupling inductance of about 3 henrys is required (see reference in footnote 5, *ante*). For over-compensation at 50 cycles per second, the coupling capacity C'' works out to be about 5.0 microfarads, a value which is appreciably greater than the 2.0 microfarads customarily employed. The calculation assumed a transformation ratio at the coupling inductance of unity. If this is not the case, the value of C' must be multiplied by the square of the transformation ratio and rapidly becomes very great. Whilst, therefore, the calculation is of some value for the triode because it may indicate that, in certain cases, the usual 2.0 microfarads is much too small, at the same time it has little value as a means of augmenting power on account of the inconveniently large capacities required and the relatively small augmentation. On the other hand, a pentode of resistance 60,000 ohms calls for a coupling inductance of 40 henrys, which gives $C' = 0.25$ microfarad for unity transformation ratio, a value of capacity which means an economy in condenser cost together with a degree of power augmentation which is of practical importance.

Experimental curves illustrating this and other aspects of the above analyses will be found in a paper published by the Author in *The Wireless World and Radio Review*, 29th June, 1932, and for this reason further illustration will be limited in the present contribution to Fig. 8, which indicates the improvement effected in a pentode experimental power response curve when the coupling condenser is reduced from 2.0 microfarads to 0.3 microfarads. The condition is approximately that of level compensation to 50 cycles per second.

Radio Research Board (of Australia) Reports Nos. 2, 3, and 4.

Report No. 2. Investigations on the state of polarisation of sky waves and height measurements of the Heaviside layer in the early morning, by A. L. Green. Pp. 80, with many diagrams.

Report No. 3. The influence of the earth's magnetic field on the polarisation of sky waves, by W. G. Baker and A. L. Green. Pp. 32, with 5 diagrams and addendum.

Report No. 4. A preliminary investigation of fading in New South Wales, by A. L. Green and W. G. Baker; Studies of fading in Victoria, on medium waves at short distances, by R. O. Cherry and D. F. Martyn; Observations on distant stations in which no ground wave is received, by R. O. Cherry. Pp. 59, with many diagrams.

Issued by the Council for Scientific and Industrial Research, Melbourne, Australia.

Interference.*

Notes on Methods for Elimination of Interference Caused by Non-radio Devices.

By E. T. Glas.

(Assistant Engineer, Swedish Board of Telegraphs.)

THE different kinds of interference caused to broadcast reception by various types of apparatus, fed from the mains, can be divided into: *low-frequency* (LF) and *high-frequency* (HF) phenomena. As in most practical matters, no sharp boundary-line can be drawn between the two species. However, no one will hesitate to characterise the well-known interference caused by a mercury rectifier with a fundamental frequency of 300 p.p.s. (6-phase rectifier) as a LF phenomenon, although it may contain HF components to some extent, nor will anyone be doubtful when confronted with a violet ray apparatus, where the fundamental frequency is usually about 200,000 p.p.s., as to the HF nature of the interference produced, although the exciting interrupter gives rise to a LF component too. As a rule, one of the two distinct components is predominant, and in most cases met with in practice this is the HF component.

As the causes of LF interference are usually well known and easily accessible to investigation, we may concentrate on the causes of HF interference. In the first place this interference seems to admit of being explained in one of the two following ways.

1.—The source of interference has the properties of a HF electromotive power, which gives rise to HF currents entering the mains.

2.—The source produces travelling pulses (which may be quite "aperiodic"), these pulses acting on periodic circuits, connected to the mains in some way, by means of shock-excitation.

In fact, experience shows that the actual interference in several cases is not affected by the insertion of an appropriately designed LF filter in the leads to the source, although oscillographic observation indicates that every irregularity of the supplied current, accessible to LF investigation, is smoothed out. The explanation is simple if we accept alternative 1, the HF currents passing the LF filter, because the natural capacity of its coils is comparatively high. This capacity cannot be sufficiently eliminated without the inductance becoming too small for a complete smoothing action.

Thus, alternative 1 accepted, we may turn to the nature of the source. It is well known that the existence of a sparking gap of some kind or other is accompanied by radio interference. When the current through the gap tends to be large, the sparking effect usually gives place to a more or less stationary arc, and the corresponding interference will greatly diminish. However, arcs are liable to cause interference owing to the introduction of a negative resistance, the generated oscillations being modulated by such causes as mains noise, ozone-cleaners for factories, medical lamps, etc. As a rule arcs are nevertheless non-interfering. A typical example is afforded by the tramways, where experience clearly shows that the interference is strongest when the current consumed sinks to a minimum, *i.e.*, when the car is coasting and only the lighting system is fed. Moreover, the interference decreases on wet days owing to the easy formation on such days of true arcs in vapour. Any leakage, particularly in high-tension power lines, is accompanied by, it may be invisible, sparking effects and the corresponding interference will reveal the faulty insulator.

When studying any case of interference, it is essential to pay regard to three fundamental factors, namely, the wavelength of interfering currents, the time-curve of currents, and the propagation path from the source to the receiver.

1. Wavelength—As a rule most commutator-machines of a small and moderate size (power < 10 kw) cause the worst interference on the lowest broadcast-waves, $\lambda = 200 - 300$ m. Simple breaking-devices, as those of flashing-lamps, controlling

* MS. received by the Editor, April, 1932.

switches and relays of various types, on the contrary, are often most troublesome on the higher waves, $\lambda = 1{,}300 - 1{,}900$ m. The same may be said of violet-ray apparatus, where the actual wavelength of the tuned circuits falls within this range. Leakage, too, gives rise to considerable interference on the higher waves. With regard to arcs, fed from d.c. mains, the wavelength of the maximum interference will be found in some

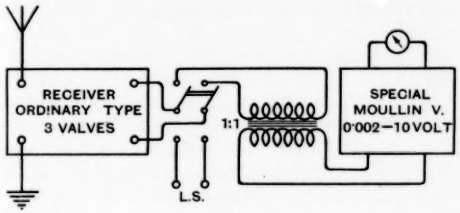


Fig. 1.

cases to change with time, owing to variable conditions of the arcing gas.

2. Time-curve of Current.—This factor is less accessible to direct observation except as regards the irregularities of the LF envelope. However, the indirect results must not be overlooked, as in the case, for instance, of a commutator machine. When one and the same machine of this kind (machine for d.c. or a.c.) is fed alternately with d.c. and a.c., the interference will be very different in the two cases and practically always at its worst in the latter case, where the commutating action is not very good, resulting, among other things, in an unfavourable time-curve.

3. Propagation Path.—Here we have to discriminate between two entirely different modes of propagation. The interfering currents may follow the mains direct to the receivers or may create induction or radiation fields, thus acting through free space, at least to some extent. Although both modes of propagation are met with in most cases, the former usually predominates, as might be expected. Even if this should not be the case, existing metallic wires and other parts have such great influence on the propagation, that the actual interfering effect is governed more by the situation with regard to the mains, etc., than by the geometric distance. Of course, the inductive influence is greatest in the case of apparatus designed to produce HF, such as violet-ray devices.

The three above-mentioned factors have been investigated by comprehensive practical study combined with measurements. There is, however, some doubt as regards the proper method of making such measurements. It has been established that the form of the time-curve is of great importance. As this can only be investigated by difficult and lengthy HF methods, the matter would be considerably simplified if an ordinary measurement of average values, such as a Moullin voltmeter,* could be employed. In fact, practice has shown that this can be done except in some extreme cases, where the ear alone must be relied upon. Fig. 1 shows the circuit that was used. The receiver must be operated at a normal HF input from a (local) broadcast transmitter. This cannot be done during the measuring procedure, but the results must be checked by the ear afterwards, while listening to a programme. If not, serious mistakes may be made. This quantitative method is of considerable advantage when studying the effect caused by altering the electric constants of an anti-interference device.

Before giving the results we will consider the design of such a device in the HF case. By far the simplest procedure, when the source is attacked, is to shunt a condenser

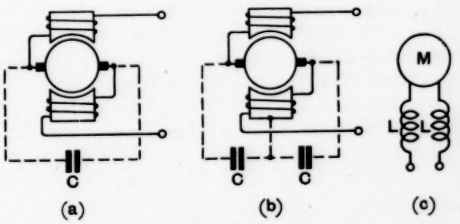


Fig. 2.

directly across the brushes or other contacts where sparks are generated (Fig. 2a). In the case of electric machines we can further take advantage of the capacity between the frame and the windings, by using two condensers

* When this instrument has a true square-law characteristic, the R.M.S. is measured independent of the curve-form. It is sometimes of considerable advantage to interconnect a filter, which cuts off very low and very high frequencies, according to the curve of sensibility of the human ear.

and connecting the midpoint to the frame of the machine* (Fig. 2b.) Where this arrangement proves to be satisfactory, ex-

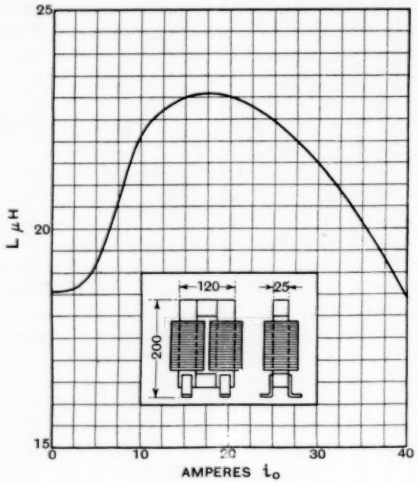


Fig. 3.

perience has shown that the following are the most appropriate values of capacity,

small motors	$C = 0.1\ \mu F$
larger motors, generators	$C = 2 - 4\ \mu F$
unshielded circuit breaking devices	$C = 0.5 - 2\ \mu F$

In many cases, however, especially with a.c., the condenser method is ineffective, even when the condenser is combined with a series-resistance. The next step is to introduce an inductance, as shown in Fig. 2c. Here practice shows that good values are, for

electric machines	$L = 0.5 - 1.5$ mH
circuit breaking points	$L = 0.1 - 1.5$ mH

according to the conditions.

The design of the coils may be discussed. Investigation has shown that a coil with iron usually has only slightly more inductance at HF than the same coil constructed without iron, although the inductance at LF may be 50 times as high in the former case. On the other hand, the unfavourable natural capacity of the coil is increased several times by the presence of iron. Thus there does not seem to be any reason to adopt iron when the interference has a pure HF character. Where this is not the case, as for instance in a small generator or a motor of considerable size, fed from a relatively small local power supply, coils with iron will very often prove to be superior owing to the existence of a LF component, which may attain 30 per cent. of the total interference (as shown by measurement of rectified average voltages). When iron is used, care must, of course, be taken to prevent saturation. This is best done by leaving an appropriate air-gap in the magnetic path. Thus coils of at least 20 mH, measured at $\omega = 2\pi \cdot 2{,}000$, can be constructed at a reasonable cost. Their inductance at HF will nevertheless seldom exceed 0.5 — 1 mH, the natural capacity is usually of the order of 300–700 $\mu\mu$F, all values applying to coils designed for a maximum continuous current of about 50 amps. d.c. Fig. 3 shows the influence of current load on inductance for such a coil of commercial construction, at LF. When the current does not exceed say 8–10 amp.—and the HF component is predominant—coils should always be designed without iron. By well-known methods of winding, the natural capacity in this case can be lowered to about 10 $\mu\mu$F at an inductance of 1 — 1.5 mH, without disregarding economy.†

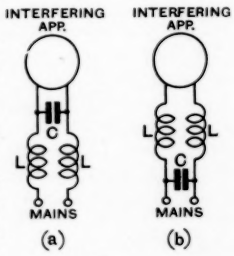


Fig. 4.

The last step is to introduce complete HF filters, which unfortunately will very often be found quite necessary for circuit breaking points such as relays, switches, keys, etc., and also for several types of electric machines, particularly big ones.

* In the a.c. case any dangerous capacity-current should be avoided by inserting a protecting condenser ($\leqq 5{,}000\ \mu\mu$F) in the lead from the midpoint of the series condensers to the frame. Where a *reliable* earth is present, this safety-rule can be neglected of course, but it is of importance in many cases (vacuum-cleaners, fans, etc.), where the frame may not be insulated and, moreover, easy to touch.

† It is, of course, not quite true to look upon the natural capacity as simply shortening the coil, when this capacity is not very large. However, a more intimate study reveals that the said capacity comes out to be chiefly harmful when constructing a reasonable choking coil for frequencies within the broadcasting range.

Fig. 4a, b shows the two simplest forms of symmetrical HF filters, the electrical symmetry being generally of advantage for the elimination. When shall type a be used, when type b? This, of course, greatly depends on the impedances of the source and of the network in relation to each other. Let us consider a simplified circuit according to Fig. 5, where the internal impedance of the sources is replaced by a lumped resistance. Instead of assuming a pure sine E.M.F., we may consider an E.M.F of the more general form of Fig. 6.

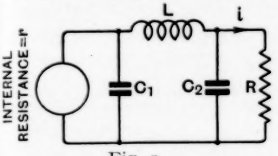


Fig. 5.

First taking $C_2 = 0$ the method of Heaviside gives the symbolical formula,

$$i = \frac{E}{rLC_1} \cdot \frac{p\omega}{\{(p+\beta)^2+\omega^2\} \cdot \left\{p^2 + p\left(\frac{R}{L} + \frac{1}{rC_1}\right) + \frac{1}{LC_1}\left(1 + \frac{R}{r}\right)\right\}} \quad (1)$$

where $p = d/dt$.

If, however, $C_1 = 0$ we have

$$i = \frac{E}{RLC_2} \cdot \frac{p\omega}{\{(p+\beta)^2+\omega^2\} \cdot \left\{p^2 + p\left(\frac{r}{L} + \frac{1}{RC_2}\right) + \frac{1}{LC_2}\left(1 + \frac{r}{R}\right)\right\}} \quad (2)$$

It appears immediately that the two formulas are quite identical but for the reciprocal substitution of r by R and *vice versa*. The generated current of the forced

Fig. 6.—$e = E \cdot e^{-\beta t} \cdot \sin \omega t$

$$= \frac{p\omega}{(p+\beta)^2+\omega^2} \cdot E$$

angular frequency ω is here of interest, and for this component we have ($p = -\beta \pm j\omega$) from . . . (1)

$$i_\omega = \frac{E}{rLC_1} \cdot e^{-\beta t} \cdot \frac{\sin(\omega t + \phi_1)}{\sqrt{\left[\frac{1}{LC_1}\left(1 + \frac{r}{R}\right) - \beta\left(\frac{r}{L} + \frac{1}{RC_1}\right) - \omega^2 + \beta^2\right]^2 + \left[\omega\left(\frac{r}{L} + \frac{1}{RC_2}\right) - 2\beta\omega\right]^2}}$$

As the curve-form is extremely variable in most practical cases, we can substitute a series of HF pulses. One of these will produce a current corresponding to $\beta \to \infty$, the square-root thus becoming independent of the circuit-constants and

$$|i_\omega| = \frac{E}{rLC_1} \cdot e^{-\beta t} \cdot f_1(\beta,\omega) \quad .. \quad (1a)$$

Similarly from . . . (2)

$$|i_\omega| = \frac{E}{RLC_2} \cdot e^{-\beta t} \cdot f_2(\beta,\omega) \quad .. \quad (2a)$$

Consequently a condenser C_1 should be found preferable, when the internal "resistance" of the source is much greater than the network impedance ("small" machines),

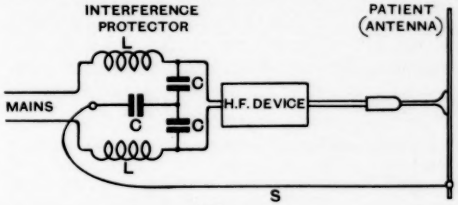


Fig. 7.

whereas a condenser C_2 should be adopted in the opposite case ("big" machines). This has been fully confirmed by practice. Thus the arrangement shown by Fig. 4a has proved to be suitable for small machines and to afford the only reliable method in the case of circuit breaking points, Fig. 4b for machines, the power of which exceeds about 2 kW. This fact does not seem to have been fully recognised in the construction of several anti-interference-devices now on the market. As a rule, the field-coils of a series-machine cannot be regarded as effective chokes at HF owing to their large distributed capacity.*

Before leaving this question we might consider a very special type of device, namely, the type designed for the elimination of interference caused by violet-ray apparatus (Fig. 7). Such a device has two functions, *viz.*, choking the mains-leads and preventing excessive induction from the patient's body. The latter function is performed by the metallic lead S, which transforms the open circuit of the body into a closed circuit with

* For unshielded breaking-points, however, a considerable choking effect of such coils is found to exist, *e.g.*, for ringing-bells.

less pronounced action at a distance. Nevertheless, the choking device must be carefully designed with coils of an inductance of the order of 50 mH, and condensers not smaller than 5,000 $\mu\mu$F. Of course, a Faraday cage could be safely used to prevent induction. The above arrangement, however, will often do. Where the interference is purely of a LF nature, the general design of the device can be maintained, but inductance and capacity must be increased. While HF interference is best attacked at the source, the LF type can usually be completely eliminated at the receiver as well. A particularly important case is the smoothing of the pulsating current from mercury rectifiers. Here a filter consisting of one coil with iron, inductance not less than 2 H, and a condenser of 4–6 μF, shunted across the leads on the receiver side, has been found commercially possible, when the current consumption of the receiver does not exceed 0.3 amp.

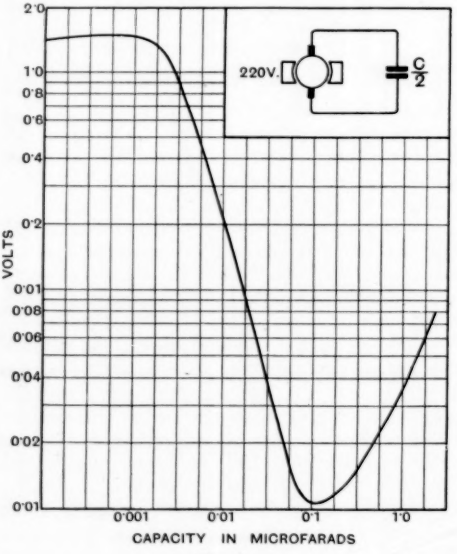


Fig. 8.

Some results of the above-mentioned measurement of average interference-voltages are shown in Figs. 8 and 9. The curves represent the interference from an adding-machine, Fig. 8 dealing with the interference from the motor (1/20 HP, 220 volt d.c., 1,725 r.p.m.) and Fig. 9 that from the start-and-stop key. Appropriate schemes of protective devices will be seen from the drawings. The optimum values of the electrical constants (L and C) can easily be extracted. Note, in particular, the influence of the in-

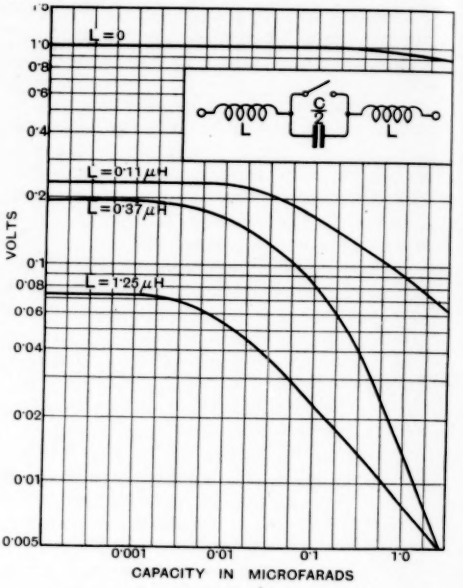


Fig. 9.

ductance in Fig. 9. If coils of a certain minimum value of inductance are not inserted, condensers are of no avail, no matter how large. Other curves of interfering devices not reproduced here show a marked resonance-effect for a certain value of the capacity, especially when the coils are very small. Such points must be carefully avoided, as otherwise a pronounced deterioration may result instead of the desired elimination of interference.

To conclude this brief survey, some words should be said about the elimination of interference from sliding contacts, such as those of tramways. The only way of solving this problem seems to be the installation of bows having the proper mechanical and electrical qualities to prevent the generation of sparks. Two different designs have been adopted in practice, namely, bows of iron (with copper-edges and lubrication grooves), called Fischer-bows, and bows furnished with carbon.

Correspondence.

Letters of technical interest are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

High-Selectivity Tone-Corrected Circuits.

To the Editor, The Wireless Engineer.

SIR,—Since the Radio Research Board considered the subject of High Selectivity Tone-Corrected Receiving Circuits of sufficient importance to appoint a special committee to investigate and report upon the merits of receivers of this type, one would have expected a journal of the standing of *The Wireless Engineer* to have dealt with the subject in an unbiased and comprehensive manner.

Instead of this, the writer of the Editorial dealing with the subject in your November issue allowed himself to be flustered by newspaper articles to such an extent that he failed to appreciate the importance of the subject with which he was dealing, and allowed his natural bias to carry him away to such an extent that he even criticised the report itself; but on this point G. W. O. H. can safely be left to his colleagues.

If G. W. O. H. could have forgotten that he was a member of the Radio Research Board, and in his capacity as journalist endeavoured to present an unbiased and explanatory criticism of the Report for the benefit of your readers, he would have found numerous important facts concealed in the verbiage of the Report, which facts are of fundamental importance to the wireless industry, and should have been made clear to your readers.

Apart from these facts, G. W. O. H. might have remedied the omission of his Board, and in fairness to me made it clear that the Special Committee referred to was really appointed to investigate my discoveries (the "Stenode") as a direct result of the early demonstrations which I gave to certain scientists who happen to be members of the Radio Research Board, including Prof. E. V. Appleton, Mr. Watson Watt, and Col. Fuller, at which demonstrations they admitted that the "Stenode" had revealed new phenomena in wireless, which phenomena were of sufficient national importance to warrant a Government investigation.

Instead of giving me credit for these discoveries, G. W. O. H. preferred to follow the lead of his Board and endeavoured to conceal rather than reveal in a tangible form the true facts.

Probably the last paragraph of the article was put in to make up the requisite number of words for the Editorial, but surely it is not the function of your Journal to give its readers a lesson in spelling, and one would have thought that if G. W. O. H. wished to be such a purist he would have remedied such spelling defects in the early drafts of the Report, of which, presumably, he had copies.

J. ROBINSON.

London, W.1.

[It is not clear from the above letter whether Dr. Robinson regards the Radio Research Board or Mr. Colebrook or Prof. Appleton or G. W. O. H. as the chief villain of the piece. That will depend on whether he considers the greater criminal to be he who conceals in verbiage numerous facts of fundamental importance to the wireless industry, or he who fails to find them and make them clear. The Editorial made no pretence of dealing with the subject in a comprehensive manner—that was unnecessary, as it had been done very thoroughly by Mr. Colebrook in the Report itself—but we do say, unhesitatingly, that it was entirely free from bias, even from "natural bias," which is presumably a kind of original sin.

There is one point in the Editorial to which we should like to refer. We said that the effect of the suppression of a neighbouring carrier by means of the quartz crystal rejector would be somewhat like a piano with one or two notes missing. We said "somewhat" because the notes would not be entirely missing unless the corresponding side-bands on both sides of the carrier were suppressed, but we confess that even then the analogy is hardly fair, because the reduction of loudness due to the elimination of one side-band would probably be much less than the analogy suggests, and might, indeed, be hardly noticeable in ordinary use.

What the newspaper articles are to which Dr. Robinson refers we do not know; we referred to one only, and that the one with which the "Stenode" burst upon an astonished world. Rightly or wrongly we have always regarded this as having been inspired by Dr. Robinson, but we certainly never allowed ourselves to be flustered by it. The Editorial Note drew attention to the Report, the price, and where it could be obtained, gave a brief historical preamble showing how interest in the subject had arisen, and after a brief summary of the results of the investigation, concluded by discussing one or two points of minor importance, but yet of sufficient interest, in our opinion, to merit reference. Dr. Robinson little knows how much time an Editor spends modifying spelling, symbols, and grammar: we have even taken the liberty of correcting the grammar of his letter. It becomes a habit.

We should like to emphasise that the Report was not concerned with the distribution of credit for discoveries, but only with a scientific investigation of a much discussed problem, and we respectfully decline the invitation to rush in where the Radio Research Board feared to tread. References were given throughout the Report and in the bibliography to the work of those who had published anything throwing light on the subject, and if Dr. Robinson plays a very small rôle in the list the blame does not lie at the door of *The Wireless Engineer*.

At the foot of p. 605 we gave a list of names of those who had contributed articles on the subject to this journal. This list should have included the names of Professor Appleton and Mr. Boohariwalla, whose article was published in March of

this year. Although the list made no pretence of being complete, this paper should have been mentioned, as it is discussed in the Report.—G. W. O. H.

"Capacitative."

To the Editor, The Wireless Engineer.

SIR,—My attention is directed to an *obiter dictum*, which, I confess, I view with certain misgiving, and which I note with amazement appears above the renowned denominant "G. W. O. H." in the Editorial column of your journal for November, 1932.

This concerns the abrogation—I might call it wanton dereliction—of a syllable of the word which I have designated above. While I have every sympathy with your eminent contributor in his laudable campaign for brevity coupled with clear thinking, I cannot but remember that almost equally renowned savants have shared with me the euphonic if longer form of this word in the past.

I am humbly aware that precedent in the form of prior use is no concrete argument because of the notorious negligence of genius in details. Nevertheless, in my stumbling research for truth I have come upon "confirmive" evidence in several dictionaries that "capacitative" may be thought to be formed from "capacitate," not by removal and substitution, but by addition.

It is in no carping or "argumentive" vein that I approach this matter; I would like to know, however, whether your contributor's statement is "representive" of your own opinion, and is therefore to be taken as "authoritive"?

Nt. Harrow. J. C. WILSON

To the Editor, The Wireless Engineer.

SIR,—I am shocked and horrified at the last paragraph of your current Editorial.

Ever since a stern comment appeared in your columns in respect of the lapses from pure English which took place at a certain I.E.E. meeting, I have regarded your Technical Editor as one before whose "authoritative" pronouncements sinners like myself might well quail, but if they are only "authoritive," how can I consider them in the same light?

I cannot waste your space in an attempt to expound my contention that the word "capacitative" is etymologically correct, but I implore Dr. Howe to investigate the Latin origins of the words at issue and then to reconsider his verdict. Any assurance that we may be spared the compulsory use of analogous abbreviations such as "qualitive," "quantitive," etc., will be anxiously awaited by "TOO TOPPY."

Hampstead, N.W.3.

Successive Heterodyne Receivers.

To the Editor, Wireless Engineer.

SIR,—In his paper in the November issue of *Wireless Engineer and Experimental Wireless*, Mr. E. L. C. White is hardly correct in attributing novelty to the practice, described in *The Wireless World's* article of May 6th, 1931, of feeding signals to the grid and heterodyne to the anode of a bottom-bend triode detector, as this method was described seven years before the article in question, in British Patent Specification No. 226,050 (1924).

Considerations stressed in the Shorter Catechism led me in 1923 to adopt "anode-fed" front-detector circuits, with a screened heterodyne, in the pious hope that the few centimetres anode-grid capacity of the detector might not pass enough heterodyne power through two loosely coupled circuits (tuned not to heterodyne but to signal frequency) to cause appreciable heterodyne radiation. It remained for N. P. Hinton, in 1927, to devise oscillator circuits with "overhang" and to *neutralise* the interelectrode capacity of an anode-fed detector, and for Mr. E. L. C. White, in 1932, to show us, with a four-electrode valve, the best way of avoiding heterodyne radiation. *Palmam qui meruit ferat!*

C. R. BURCH, Research Department.
Metropolitan-Vickers Elec. Co., Ltd.

Book Review.

The True Road to Radio.

By Albert Hall, A.R.C.Sc., M.I.R.E., Wh. Ex. Ferranti, Ltd., Hollinwood, Lancashire. 3rd edition.

The object of this book is to give a comprehensive survey of the principles of wireless as applied particularly to high quality receiver design, and in this it succeeds admirably. The treatment adopted is first to describe the problem in simple terms, secondly to investigate the matter technically, and thirdly, to illustrate the practical results obtainable by measurements on Ferranti apparatus.

A large section of the book is devoted to tuning systems and high-frequency amplification; the superheterodyne, however, is only cursorily touched upon, and no mention is to be found of such a recent development as the variable-mu valve; this is, we understand, because to include this material would have meant an unjustifiable delay in publication of the new Edition which was in demand. Both anode bend and grid detection are thoroughly dealt with, and low-frequency and power output stages are treated with a wealth of illustrative data. The use of valve curves for determining the optimum operating conditions is stressed, and numerous examples are given. It seems to the reviewer, however, that a note should have been included to the effect that the curves illustrated are not necessarily applicable to valves at present available under the same type numbers, but to older specimens. It is unfortunate also that an error should have crept into the section dealing with resistance-capacity coupling, wherein it is stated that if the grid leak be increased in value so also must the coupling condenser be increased in capacity. Actually, of course, the coupling capacity is inversely proportional to the resistance of the grid leak.

Although the treatment is largely non-mathematical, a number of formulae are included as an aid to design; those intending to employ them, however, should note that they are not entirely free from printing errors. The book is profusely illustrated and the numerous curves and other data relating to Ferranti components render it as useful for reference as for its more legitimate purpose of explaining the nature of the problems of receiver design and indicating at least one method of solving them.

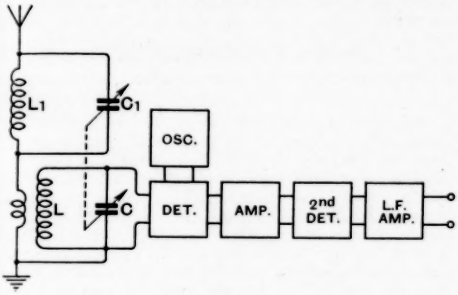
Some Recent Patents.

The following abstracts are prepared, with the permission of the Controller of H.M. Stationery Office, from Specifications obtainable at the Patent Office, 25, Southampton Buildings, London, W.C.2, price 1/- each.

SUPERHETERODYNE RECEIVERS.

Application date, 26th March, 1931. *No.* 375410.

In order to eliminate second-channel interference in a superhet set, more particularly one of the type in which a low intermediate frequency is used,



No. 375410.

say, 40 kilocycles, a rejector circuit L_1, C_1 is inserted in, or coupled to, the aerial, and is so ganged with the ordinary input circuit L, C as to maintain a constant "difference" frequency, equal to twice the intermediate frequency employed. Both the rotor and stator of the condenser C_1 must be insulated with respect to earth. A construction of condenser suitable for ganging the two circuits together is described in the specification.

Patent issued to J. Robinson and British Radiostat Corpn., Ltd.

TELEVISION SYSTEMS.

Application date, 6th February, 1931. *No.* 374094.

Relates to scanning-apparatus of the type in which a rotating apertured drum co-operates with a rotating mirror-wheel set at right-angles to the drum. In an arrangement designed to scan an object in fifty lines, fifteen times per second, over a square area, the apertured drum is 9.7 inches in diameter with thirty apertures each 0.017 inch square. The mirror wheel is 9.5 inches in diameter and is fitted with twenty-five tangential mirrors each 2 by 1.2 inches. The motor speed is 1500 revs. per minute, the drum being driven through reduction gearing at thirty-six revs. per minute. This enables a picture ten feet square to be covered at a distance of approximately twenty feet from the mirror.

Patent issued to Marconi's Wireless Telegraph Co., Ltd., and H. M. Dowsett.

Convention date (U.S.A.), 2nd April, 1930. *No.* 374974.

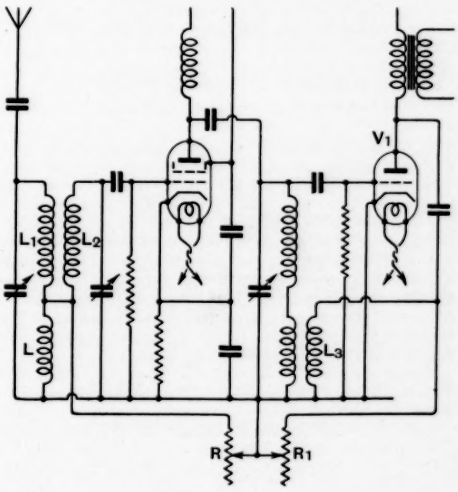
To allow the received picture to be "monitored," provision is made to project a second facsimile picture for the information of a station supervisor outside the cabinet containing the main observer, and without obstructing the latter's view of the primary reproduction. The spiral line of apertures on the scanning-disc overlaps the full 360° by an extra 90°, and a part of the emission from the Neon lamp is diverted through a mirror-and-lens system to pass through a part of the scanning-disc separated by 90° from the part through which the main picture is viewed. A second mirror on the far side of the scanning-disc then reflects the secondary picture through a window in the observer's cabinet to the supervising attendant outside.

Patent issued to Electrical Research Products Inc.

VOLUME AND SELECTIVITY CONTROL.

Application date, 24th March, 1931. *No.* 375357.

A resistance R in parallel with a coil L coupling the two tuned circuits comprising L, L_1, and L_2, of a band-pass input serves as an input volume control which does not disturb the tuning of the ganged circuits. In addition it can be used to regulate the band-width passed by the filter circuit, and therefore the selectivity of the set as a whole. A second resistance R_1 is inserted in parallel with a



No. 375357.

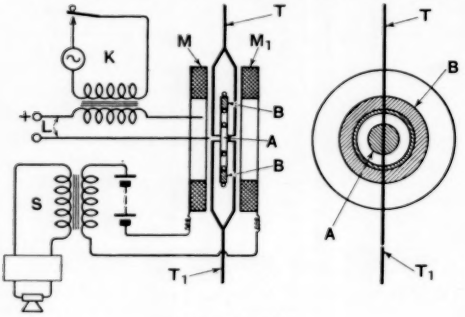
back-coupling coil L_3 in the output of the detector valve V_1 in order to control reaction. The two resistances R, R_1 are coupled together as shown.

Patent issued to F. Murphy and E. J. Power.

HIGH-FREQUENCY GENERATORS.

Convention date (U.S.A.), 14th July, 1930.
No. 374311.

High-frequency currents are generated by applying a breakdown voltage from leads L across two concentric electrodes A, B mounted inside a gas-filled container (not shown). As soon as the arc is formed it is made to rotate rapidly, around the annular gap between the electrodes, by the magnetic



No. 374311.

field from two solenoids M, M_1. In its rotation the arc, or discharge current, induces a rapidly alternating EMF in the bifurcated ends of a pick-up wire T, T_1 which is used as a transmitting aerial. Morse signals may be superposed by a keying-circuit K coupled to the supply leads L, or speech signals from a microphone circuit S coupled to the solenoid windings M.

Patent issued by Marconi's Wireless Telegraph Co., Ltd.

REMOTE TUNING-CONTROL.

Convention date (U.S.A.), 18th October, 1930.
No. 372687.

In order to tune a superheterodyne set from a distance, the local oscillator in the set is of the multivibrator type, wherein the generated frequency depends upon the value of one of the circuit elements, for instance the grid leak or the anode coupling-resistance. The space-current path of an auxiliary valve is arranged in parallel with this frequency-determining element, and the internal impedance of the auxiliary valve is then adjusted from a distance by means of a grid-bias rheostat. The frequency-adjusting rheostat is conveniently combined with a volume-control potentiometer.

Patent issued to Marconi's Wireless Telegraph Co., Ltd.

TWO-WAY TELEVISION.

Convention date (U.S.A.), 1st October, 1930.
No. 371612.

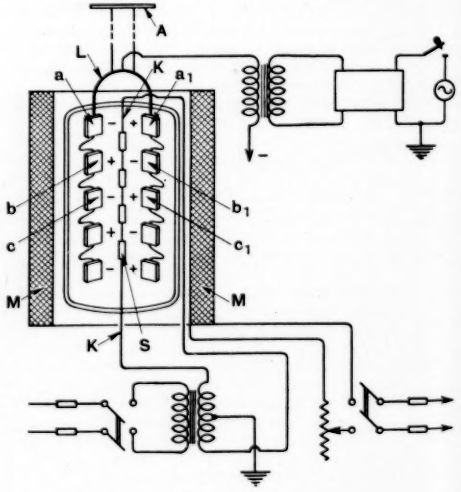
In a two-way television system the analysing system at the receiving end is also utilised to "monitor" the outgoing transmission, so as to give what might be called a "sidetone" representation to the local subscriber of the picture of himself that is being sent to his distant correspondent. The incoming picture is built up by means of a scanning arrangement of the kind in which an electric arc is traversed in zig-zag fashion along a series of interleaved electrodes by the action of a magnetic field created by an electric current encircling the electrode system. A local oscillator superposes an alternating current on the electrode system whereby the latter reproduces, during alternative half-cycles, the incoming picture of the distant correspondent, and during the intervening half-cycles serves as a mirror in which the local correspondent may observe how his image is appearing on the screen at the distant point.

Patent issued to Communication Patents Inc.

SHORT-WAVE OSCILLATORS.

Convention date (U.S.A.), 21st July, 1930.
No. 375095.

Wavelengths of the order of decimetres are generated in a valve of the split-anode "magnetron" type by making each of the anode sections electrically long relatively to the generated wave, and setting them close to each other so as to increase their mutual inductance. As shown each anode consists of a number of "targets" a, b, c, etc., and a_1, b_1, c_1, etc., connected in series by looped wires. The central cathode K is screened at intervals by sleeves S, so that the electron stream is concentrated on the "targets." The whole assembly is surrounded by a solenoid M, producing an axial magnetic field. The effect of this upon the transverse electron stream is to create a standing-wave on the sectionalised anodes, as indicated



No. 375095.

by the progressive + and − signs. The anode sections are connected at their upper ends by a looped wire L, from which the HF energy is tapped off to a radiating aerial A.

Patent issued to Marconi's Wireless Telegraph Co., Ltd.

SCANNING FOR TELEVISION.

Convention date (U.S.A.), 7th August, 1930. No. 375589.

A single rotating cylinder is arranged to give an equivalent scanning-point to that produced by two separate rotating discs with intersecting scanning-lines. The rim of the cylinder is made sufficiently wide to accommodate a series of inclined parallel slots. Light from a Neon lamp is projected by a lens through one of the slots on to a double set of right-angled prisms, which reflect the image of the slot back through a slot on to a lower point of the same cylinder. Owing to the double reflection through the prisms, the image of the original slot is rotated through 90°, so that it intersects lower slot at right angles, so as to produce a single scanning "point."

Patent issued to A. J. Cawley.

ELIMINATING "MAN-MADE" STATIC.

Convention date (U.S.A.), 25th February, 1931. No. 375737.

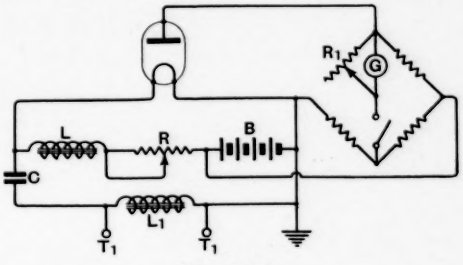
The specification analyses local interference into: (a) that carried by the electric mains which are the common source of supply for domestic labour-saving apparatus, lifts, violet-ray appliances, and other sparking-devices, as well as for the receiving set; (b) field "pick-up" by the aerial and the lead-in, as well as by the coupling-coils in the set, such "fields" being of comparatively limited spread. According to the invention, a receiving set is rendered substantially immune from such interference (1) by locating the aerial in some remote place, say on the top of the roof of an hotel or apartment house, outside the area of spread of the local fields of induction; (2) by providing a screened transmission line or lead-in of low impedance, coupled to the input circuit of the receiver through a filter circuit designed to reject low-frequency disturbances due to sparking-devices. (3) The mains supply unit is also carefully screened, as well as the set, and also the opening through which the sound emerges from the loud speaker. (4) The screening-sheath covering the lead-in or transmission line from the remote aerial is preferably grounded at several points along its length.

Patent issued to Marconi's Wireless Telegraph Co., Ltd.

A.C. METERS.

Application date, 20th August, 1931. No. 376066.

A direct-reading A.C. meter, suitable for low-impedance circuits, and capable of measuring currents varying in value from micro-amps to amperes, and varying in frequency from 25 cycles to 6,000 kilocycles, is based on the known principle of injecting the A.C. current to be measured into the filament of a thermionic valve and then measuring the resulting increase in plate current. The invention is characterized by the feature that the valve is at all times adjusted to pass a saturation current, the increase in the latter, after the application of the A.C. current, giving the desired indication. As shown the filament is heated by direct current from the battery B, through a resistance R and choke L which serve to reduce the applied P.D. say to 2 volts or other rated value. A unipivot galvanometer G is inserted across the diagonal of a Wheatstone-bridge network, one arm of which contains the inter-electrode capacity of the diode or other valve. The current to be measured is applied across the terminals T, T_1, shunted by a heavy choke L_1 and passes through an electrolytic condenser C to the filament. A resistance R_1 serves



No. 376066.

to compensate the galvanometer G for casual variations in temperature.

Patent issued to H. E. M. Barlow.

GENERATING ULTRA-SHORT WAVES.

Convention date (U.S.A.), 28th July, 1930. No. 373847.

Waves a fraction of a centimetre long are generated by passing spark-discharges through a colloidal solution containing metallic particles. In operation the spark "grape vines" itself, *i.e.*, follows branched paths through the liquid and sets up a series of sub-discharges from the ends of the metallic particles. These in turn generate damped oscillations of a wavelength corresponding to the natural "period" of the particles in solution, so that with particles of uniform size the radiation is confined to a comparatively narrow band of waves. To create a more or less uniform distribution of energy, the solution may be subjected to heavy pressure, whilst further concentration is effected by means of a backing-reflector of parabolic section.

Patent issued to Marconi's Wireless Telegraph Co., Ltd.

PRODUCING CIRCULARLY-POLARIZED WAVES.

Convention date (Germany), 13th October, 1930. No. 375165.

Circularly-polarised waves, which are known to be largely free from fading effects, are produced by feeding HF energy to an aerial system consisting of two conductors twisted around an imaginary cylinder, the two spiral paths being 180° out of phase. Transverse radiators are preferably arranged along the length of each wire, and may extend inwards, *i.e.*, between the two wires, or project outwards from the double line, or both. The ends of the twisted aerials are connected together through a terminating resistance.

Patent issued to Telefunken Ges. für Drahtlose Telegraphie m.b.H.

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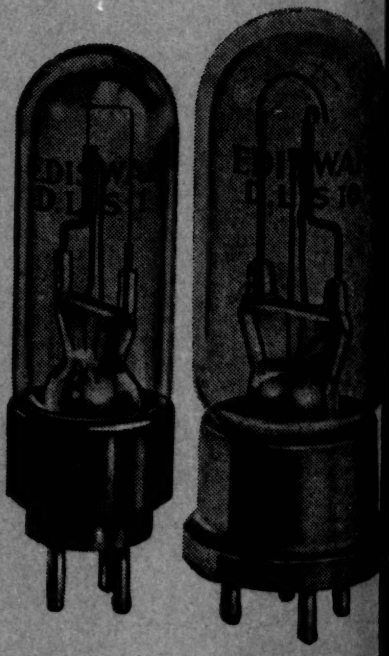

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